NASA-STD-3001 Technical Brief

Orthostatic Intolerance

OCHMO-TB-019
Rev A

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev B
[V1 3003] In-Mission Preventive Health Care

NASA-STD-3001 Volume 2, Rev C
[V2 6109] Water Quantity
[V2 7038] Physiological Countermeasures Capability
[V2 7040] Physiological Countermeasure Operations
[V2 7042] Orthostatic Intolerance Countermeasures

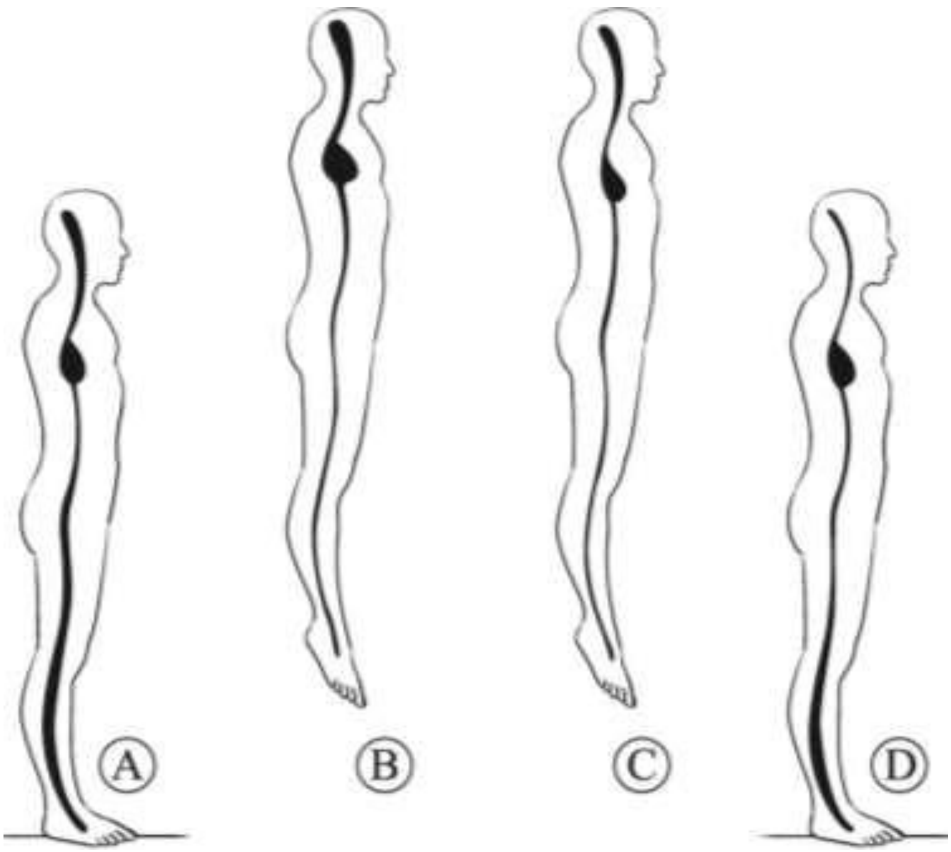
Executive Summary

Orthostatic intolerance (OI) is an abnormal response observed during return to a gravitational environment after microgravity exposure. It is triggered by upright positioning and is caused by an inability to maintain arterial blood pressure and cerebral perfusion. It can result in presyncope and, ultimately, syncope (i.e., loss of consciousness). Specifically in the spaceflight community, OI is a major concern when crewmembers are re-introduced to gravity after landing due to decreased plasma volume and sympathetic nervous system dysfunction. OI must also be considered for standing or upright crew experiencing acceleration loads. A variety of countermeasures can be implemented to mitigate OI symptoms.

Fluid loading prior to reentry is an important countermeasure to decrease OI

Background

When a crewmember enters a microgravity environment, a large number of physiological changes occur, including a significant shift in bodily fluids. Below is a chronological representation of fluid within the body of a spaceflight crewmember:



A: crewmember is on Earth; usual distribution of fluid while standing – excess fluid pooled in the lower body
B: crewmember arrives in microgravity; distribution of fluid is more towards the upper body and head due to absence of gravity and hydrostatic gradient
C: crewmember adapts to the microgravity environment (<2 days) by reducing circulating (intravascular) fluid volume by around 15%, redistribution of fluid to extracellular space
D: crewmember returns to Earth; diminished intravascular fluid volume coupled with gravitational gradient pooling fluids in the lower extremities leads to reduced venous return, decreased cardiac output, and OI symptoms

Application

Several countermeasures can be utilized to lessen the effects of OI, with the main strategy being increasing venous return or intravascular fluid volume. Examples include:

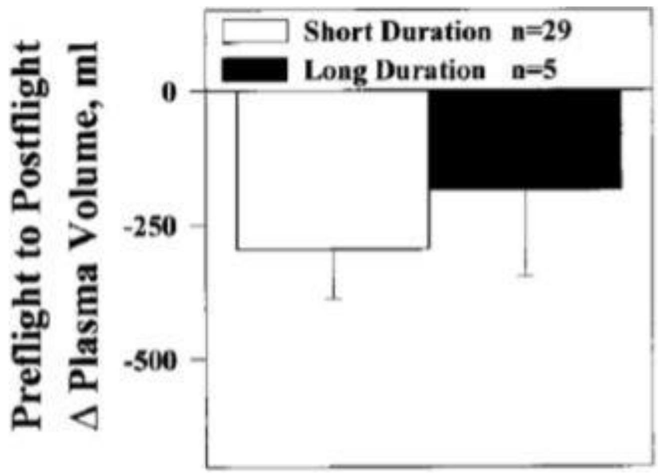
- **Inflight exercise** – aerobic or resistance; used to counteract the cardiac and muscular deconditioning accrued throughout the mission.
- **Fluid loading & salt intake** – increased intake of water with sodium chloride the day prior to landing via broth or water + salt tablet; increases intravascular volume
    - Currently protocols include the intake of 24-48 oz of NaCl-water solution before deorbit, depending on their bodyweight
- **Compression garments** – promote venous return via lower extremity compression; improved venous return reduces light-headedness and pre-syncope risk. Examples include the anti-G suit (AGS; left picture), gradient compression garments (GCG; right picture)
    - AGS provides a maximal compression of ~75 mmHg with differential settings
    - GCGs have a greater pressure in the lower leg (~55 mmHg) that gradually decreases throughout the upper leg (~30 mmHg) and abdomen (~20 mmHg); demonstrated to maintain arterial blood pressure and mitigate tachycardia

- **Cooling garments** – to reduce the heat load experienced by the crew which, in turn, reduces peripheral vasodilation and further fluid redistribution to extravascular space; may have small effects akin to compression garments
- **Pharmaceutical options** – while some data suggests benefits of pharmaceutical intervention for the reduction of OI symptoms (e.g., midodrine, octreotide), the data is limited and associated pharmaceutical effects or adverse sequelae currently limit widespread use of such medications during spaceflight
- **Artificial gravity** via short radius centrifugation – shown efficacy in bedrest studies, but unknown in spaceflight

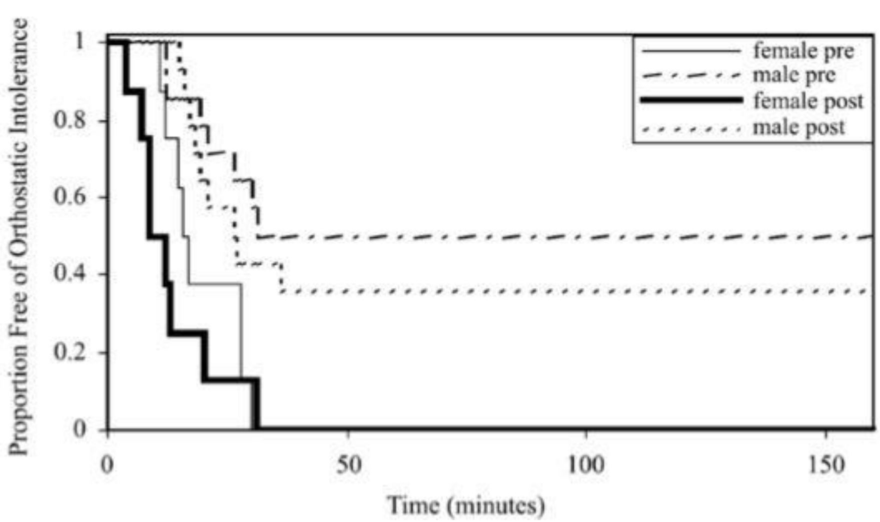
These countermeasures have individual variability, but all present limitations. In order to fully protect the crew, several methods should be used in combination to reduce the risk of OI.

Reference Data

- Cephalad (headward) fluid shifts occur when the crew enters microgravity
- Bed rest studies suggest fluid redistribution occurs within 2 days of transition to microgravity
    - 6˚ head-down tilt bed rest studies have produced similar plasma volume reduction (4-17%) to those seen in microgravity
- Apollo program noted decrease in crewmember intravascular volume after spaceflight via bodyweight measurements



- Head-down tilt bed rest studies have confirmed (via MRI and EKG) cardiac atrophy occurs within 2 weeks
    - Studies also confirm autonomic dysfunction, including decreased baroreflex sensitivity
- Large norepinephrine differences are seen between presyncopal and non-presyncopal hypovolemic test subjects
    - Presyncopal subjects had circulating norepinephrine values similar to normovolemic subjects, but non-presyncopal subjects had values ~3x those of normovolemic subjects
- There are differences in OI incidence between males and females. Females generally experience increased symptoms during tilt tests and are more prone to OI in the field. The figure (right) highlights sex-based differences in OI symptoms seen before and after prolonged bed rest. Approximately 50% of female subjects became presyncopal by 10 minutes of 30˚ tilt.



Back-Up

Major Changes Between Revisions

Original → Rev A

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev B and Volume 2 Rev C.

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision B
[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA) that takes into account the needs and limitations of each specific design reference mission (DRM), and parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Rev B for full standard).
Note: The term “in-mission” covers all phases of the mission, from launch, through landing on a planetary body and all surface activities entailed, up to landing back on Earth.

NASA-STD-3001 Volume 2 Revision C
[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 4, Water Quantities and Temperatures, for the expected needs of each mission, which should be considered mutually independent.
[V2 7038] Physiological Countermeasures Capability The system shall provide countermeasures to meet crew bone, muscle, sensorimotor, thermoregulation, and aerobic/cardiovascular requirements defined in NASA-STD-3001, Volume 1.
[V2 7040] Physiological Countermeasure Operations The physiological countermeasure system design shall allow the crew to unstow supplies, perform operations, and stow items within the allotted countermeasure schedule.
[V2 7042] Orthostatic Intolerance Countermeasures The system shall provide countermeasures to mitigate the effects of orthostatic intolerance when transitioning from weightlessness to gravity environments and during Gz (head-to-foot) vehicle accelerations defined in the sustained acceleration limits.

Reference List

1. Evidence Report: Risk of Orthostatic Intolerance During Re-exposure to Gravity – HRP, HHCE. https://humanresearchroadmap.nasa.gov/Evidence/other/ORTHO.pdf
2. Space Operations Medical Support Training Course – Space Mission Operations Division
3. Risk of Orthostatic Intolerance during Re-exposure to Gravity – Stuart Lee (Human Systems Risk Board presentation on 9/12/2019)